Managing Northern Pike at Lake Davis

A Plan for Year 2000:

Three Year Report

California Department of Fish and Game
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EXECUTIVE SUMMARY

This report presents the results of three and one-half years of implementation of *Managing Northern Pike: A Plan for Y2000*, the results of a joint planning process between the California Department of Fish and Game and the local community to control the population of and contain the non-native invasive northern pike, *Esox lucius*, in Lake Davis. Implementation of the plan is ongoing; this report presents results through June 2003.

Field crews removed 28,100 pike (4,250 pounds) from the reservoir. Yearly harvest increased annually. Over 26,000 (93%) of the pike removed were young-of-the-year, less than 12 inches long. Two hundred and eighteen were longer than 24 inches, generally three years or older. These data indicate that the abundance of pike in Lake Davis increased during that time period.

We assessed the pike plan results using four criteria which may provide an indication of pike plan success:

1. Changes in pike density in Lake Davis: The pike population grew during the first three years of plan implementation, but growth may have slowed in year four.

2. Impact to the trout fishery: Angler survey and monitoring data indicated that trout densities in Lake Davis have decreased. This may have been partly due to pike predation but was also likely a reflection of a decrease in annual stocking numbers beginning in 2000 after an unusually large stocking program in 1998 and 1999. Catch rate data suggests the density of larger pike capable of eating catchable-size trout may have remained about the same or increased more slowly than the pike population as a whole.

3. Changes in the risk of pike escaping: Increased pike abundance during the course of plan implementation increased the risk of pike escaping the reservoir.

4. Changes in the risk of human movement of pike: Although both education and enforcement activities may have reduced the risk of human movement of pike, increases in pike density (and the potential to catch and move pike) may have cancelled out these effects.

This assessment indicates implementation of the *Y2K Plan* has not stopped the growth of the pike population, reduced the threat to the trout population or reduced the threat of natural or human movement to other waters. Implementation may have slowed the growth of the pike population in Lake Davis. Nevertheless, pike compensatory strategies such as more rapid growth rates, earlier maturation, and higher fecundity when densities are low, probably cancel out the effects of removing them from Lake Davis by mechanical means.

INTRODUCTION

Since 1999, the California Department of Fish and Game (the Department), in cooperation with the Lake Davis Steering Committee, has been implementing the recommendations in *Managing Northern Pike in Lake Davis, a Plan for Y200 (Y2K Plan)*(CDFG 2000). The *Y2K Plan* recommends thirteen "control and containment" activities to control the pike population, to keep it confined to Lake Davis, and to prevent the type of pike population explosion that occurred before the 1997 rotenone treatment. The plan encourages trying new ideas and discarding the least effective ones as the results become known. None of the recommendations are proven eradication methods, but the hope of the plan is to "buy time" until an acceptable eradication method can be found. The plan also recommends monitoring fish populations to measure the effectiveness of the actions.

Implementation of the *Y2K Plan* is ongoing. We present results from the 2000, 2001, and 2002 field seasons and for the 2003 field season through June. For those recommendations that involve the physical removal of pike, we present the numbers and sizes of pike captured and, in some cases, the seasons or situations in which the recommendation was most or least effective. Following the description of the recommendation is an assessment of whether it should be continued during the next field season.

Some recommendations, such as enforcement and public education, do not result in the direct removal of pike from the reservoir. For these types of recommendations, we simply describe how they were implemented. More details on all the methods, including gear specifications, other species caught, and statistical analyses, will be available in annual field season reports.

We use four criteria to assess the results and to determine if the pike plan is achieving its goal of controlling and containing the pike population in Lake Davis:

1. Changes in pike density
2. Impact to trout fishery
3. Changes in the risk of pike escaping
4. Changes in the risk of human movement of pike

CONTROL AND CONTAINMENT

This section describes results of each of the control and containment methods. For the purposes of this report, we assume that young-of-the-year pike are 12 inches and shorter, and that pike longer than 24 inches are at least 3 years of age. These divisions are generally accurate but are not precise since there is considerable overlap between the sizes of different age fish. For example, the smallest two-year old pike may be even smaller than some of the largest one-year old pike. In addition, female pike are generally larger than the males.

Two to three field crews with a total of six to nine people removed pike each field season using the methods recommended in the *Y2K Plan*. While crews did change the amount of time spent on different removal methods, the general scale of the effort remained about the same.

Field crews removed 28,100 pike (4,250 pounds) from the reservoir through June 2003 (Table 1). Over 26,000 (93%) of the removed pike were young-of-the-year, with a total length of less than 12 inche. Two hundred and eighteen were longer than 24 inches, generally three years or older (Table 2). Each year, the number and total weight of pike removed increased through 2002. Annual catch rates through June show a drop from 2002 levels (Table 1).

The increasing catch rates 2000-2002 suggest that the pike population in Lake Davis expanded during that time. The reduced catch rates through June 2003 suggest that population growth may be slowing or, since the bulk of the catch is young-of-the-year, that 2003 was not a large year class.

Crews removed the most pike with electrofishing boats. The trap nets and commercial purse seine were useful in catching larger, spawning pike. Beach seining was useful in shallow nursery areas early in the spring. Gill nets captured a good portion of the pike and can be in place while other methods are being used. Field crews used backpack electroshockers to remove pike from the tributary creeks (Tables 2 and 3).

Table 1. Number and estimated weight of pike removed from Lake Davis from March 2000 through June 2003.

	2000	**2001**	**2002**	**2003 (through June)**	**Total**
Number of pike removed:	605	6,368	17,635	3,492	28,100
Number of pike removed ice-out through June only:	103	436	3,768	3,492	
Estimated weight of pike removed:	280 lbs.	890 lbs.	2,510 lbs.	570 lbs.	4,250 lbs.

Table 2. Number and percentage of pike removed by each recommended method from March 2000 through June 2003.

Method:	**Number of pike**	**% of total catch**
Experimental Control Measures (Recommendation #1)		
barrier net	97	0.3%
detonation cord	4	0.01%
Encourage fishing (Recommendation #5)		
reports of angler-caught pike (mostly incidental to trout angling)	80	0.3%
Drag nets and purse seines (Recommendation #6)		
gill nets	1,834	6.5%
beach seines	1,354	4.8%
purse seines	977	3.5%
Electrofishing (Recommendation #7)		
boat electrofishing	23,366	83.2%
backpack electrofishing (tributaries)	97	0.3%
Fyke and trap nets (Recommendation #10)		
trap nets	167	0.6%
Other		
dip nets	103	0.4%
larval light traps	21	.07%
TOTAL:	**28,100**	**99.98%**[1]

[1]Percentages do not total 100 due to rounding.

Table 3. Number and percentage of pike >24 inches captured by each method during from March 2000 through June 2003.

Method:	***Number of pike***	***% of total catch***
Experimental Control Measures (Recommendation #1)		
barrier net	7	3.2%
detonation cord	2	0.9%
Encourage fishing (Recommendation #5)		
reports of angler-caught pike (mostly incidental to trout angling)	5	2.3%
Drag nets and purse seines (Recommendation #6)		
gill nets	7	3.2%
beach seines	0	0.0%
purse seines	65	29.8%
Electrofishing (Recommendation #7)		
boat electrofishing	78	35.8%
backpack electrofishing (tributaries)	0	0.0%
Fyke and trap nets (Recommendation #10)		
trap nets	54	24.8%
TOTAL:	**218**	**100.0%**

1. Experimental Control Measures. The *Y2K Plan* recommends the combined use of barrier nets to contain pike with removal methods such as electrofishing, purse seines (encircling nets), and detonation cord. As a first step, crews placed a barrier net across the mouth of Mosquito Slough in December 1999 (Figure 1). Because Lake Davis has extensive pike spawning habitat, pike blocked off from one spawning area will find another area to spawn. Therefore, the Department replaced the barrier net in November 2000 with a barrier net containing a fyke, or trap. The old barrier net contained 30 pike gilled in the mesh when it was removed in April 2000. Since installation in November 2000, the revised barrier net caught 67 pike, many of which were spawning females. Seven of the pike captured were greater than 24 inches in length. The revised net was most successful in 2001 when it captured 54 pike. Low water levels during the 2002 and 2003 spawning periods caused the net opening to collapse, making it less effective.

> ***Assessment***: The barrier net will trap spawning pike when the reservoir is at a sufficient elevation. For 2004, we recommend maintenance and modification of the barrier net to improve its effectiveness at different reservoir elevations.

Another suggested experimental control method was the underwater use of detonation cord. This method was tried in a 1-acre area using pike in live cars set at varying distances. The cord successfully killed all pike at a distance up to 23 feet. The method was again used in a 13-acre area during the 2003 spawning season. Four pike, including three spawning females were killed in the blast.

> ***Assessment***: We do not recommend the further use of detonation cord in 2003 and 2004. Resources needed for the extensive preparation and implementation of a detonation cord project can be better spent on intensifying trap net and gill net use during the spawn.

2. Block tributary streams. Department crews installed several grate barriers across Cow, Freeman, and Big Grizzly Creek to prevent pike movement upstream of the reservoir. Backpack electrofish monitoring indicated that pike had not moved upstream of the barriers on Cow and Freeman Creek. Crews captured pike upstream of the Big Grizzly Creek barrier, suggesting it may not have been effective (see Electrofishing, page 10).

> ***Assessment***: We recommend that these barriers remain in place and continue to be maintained in 2003 and 2004.

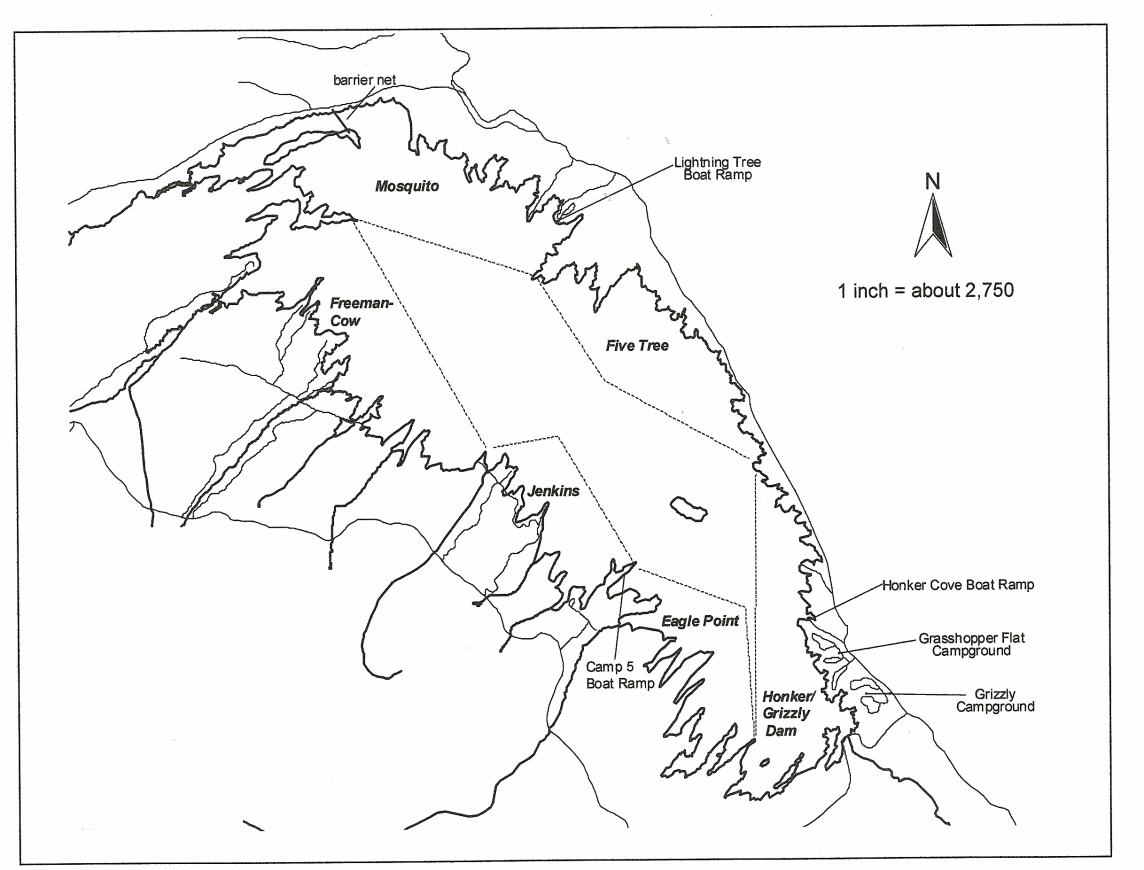


Figure 1. Location of barrier net and of six sections for electrofish monitoring, Lake Davis.

3. Block in-lake spawning areas. As described above, Lake Davis is a shallow reservoir with a large proportion of its area suitable for pike spawning. If prime spawning habitat such as the Mosquito Slough area is blocked, pike will spawn elsewhere, broadening their distribution in the reservoir. Therefore, we did not implement this recommendation except for installing the experimental barrier/trap net described above.

> ***Assessment***: Because of the large amount of suitable spawning habitat in Lake Davis, we do not recommend further implementation of this item.

4. Reduce pike food supply. Before the 1997 treatment, the Department had stocked Lake Davis with catchable-, subcatchable-, and fingerling-size rainbow trout. Catchable-size trout weigh an average of one-half pound each and range in length from 8 to 12 inches. Subcatchable-size trout are about 4 to 6 inches long. Fingerling trout weigh a maximum of one ounce and are 3 to 5 inches long.

In 2000 the Department began stocking only catchable-size rainbow trout (about 2 per pound) with an annual allotment of 50,000 to 60,000 trout.

> ***Assessment***: We recommend that the Department continue the policy of not stocking fingerling trout. We recommend continued monitoring of angler catch and the diet of large pike in Lake Davis in order to estimate the impact on catchable-size trout.

5. Encourage fishing (e.g. derbies). One of the most frequent suggestions for dealing with the pike problem has been encouraging anglers to target them through derbies or free fishing. Because of the danger of spreading pike to other waters, the Department does not want to promote pike angling. However, anglers are required to remove and kill any pike they do catch and to report the catch to the Department through its 1-888-DFG-CALTIP hotline. The Department has posted signs around the reservoir and in stores and motels in the area instructing anglers to call CALTIP when they catch a pike.

Since 2000, the Department received 80 reports of pike caught by anglers. About half of these were less than 12 inches long, although at least five were greater than 24 inches in length. Experienced anglers targeted pike during a spring 2003 trial. A total of 45 angler-hours yielded one pike about 12 inches long. These data indicate that targeting pike with rod and reel will not significantly reduce their numbers in Lake Davis. By the time pike become abundant enough for a sport fishery, angler impact would probably not be sufficient to impact their numbers.

> ***Assessment***: We do not recommend that the Department encourage pike angling.

6. Drag nets and purse seines. The *Y2K Plan* suggests the use of gill nets, trammel nets, beach seines, and purse seines. During 2000 – 2003 Department crews used gill nets and beach seines, and the Department hired a commercial purse seine operator.

Crews used gill nets with ¾-inch and smaller mesh size. They caught over 1,800 pike most of which were less than 12 inches in length. Gill nets entrained only seven pike longer than 24 inches. Larger mesh (>1 inch) nets used in 2000 captured many trout and few pike, so crews switched to smaller mesh sizes.

Crews used beach seines in the spring to locate juvenile nursery areas. They used the seines in nearshore areas less than four feet deep and removed 1,354 pike, very few of which were longer than 12 inches.

A commercial purse seine operator was employed in fall and spring. In 2000, the purse seine used a 40-foot deep and 1000 foot long net. In 2001, 2002, and 2003, the net was 20-feet deep and 800 feet long. Purse seining removed 977 pike. The purse seine captured 65 pike greater than 24 inches long, representing nearly one-third of the total catch of the larger pike with all methods combined. About 80% of the larger pike were caught in April and May.

Assessment: We recommend continued use of gill nets, beach seines and a purse seine in 2004. Gill netting and purse seining should be intensified during the spring spawn.

7. Electrofishing. Crews operated one to two electrofishing boats each day during the field season. They began electrofishing as the ice cleared from the reservoir in late March to early April and continued until November or December when ice or weather conditions no longer permitted work. During "control and containment" work, crews targeted areas known to have the highest concentrations of pike, making repeated passes over an area until catch rates declined. When monitoring, crews used the standardized approach described in the monitoring section.

We express catch rates as the number of pike captured per hour of "pedal down time," referring to the time that the electrofishing gear transmits a mild electric current through the water. Workers press the pedal in a rhythmic manner, not continuously. A typical work day includes about two to four hours of "pedal down time."

Electrofishing crews removed 23,366 pike using both methods through June 2003. The majority of these pike (93%) were young-of-the-year, less than 12 inches long. However, the 78 pike that were longer than 24 inches represent over one-third of the 218 pike caught in that size class by all methods combined. Crews removed most of the larger pike in September, October, and November.

The annual mean daily catch rate for pike during electrofishing (control and containment method) increased significantly[a] from 2 pike per hour in 2000 to 13 pike per hour in 2001 to over 31 pike per hour in 2002. At the end of June, the 2003 catch rate was 52 pike per hour. Since the bulk of the catch was composed of young-of-the year which may have a high natural mortality, we also looked at the catch rate for larger (>12 inches) pike. This grew significantly[b] from less than one pike per hour in 2000 and 2001 to over 2 pike per hour in 2002.

Each season, field crews backpack electrofished Cow, Freeman, and Big Grizzly Creeks above Lake Davis to the U.S. Forest Service Road 24N10. This

[a] $F_{(2, 731)} = 73.35116$, $P < 0.05$
[b] $F_{(2, 731)} = 30.6926$, $P < 0.05$

effort yielded 97 pike, all shorter than 12 inches. Crews captured pike above the barrier on Big Grizzly Creek in 2001 and 2002.

Assessment: Electrofishing in Lake Davis and its tributaries should be continued in 2003 and 2004.

8. Electrofishing to herd pike to traps and nets. The Department conducted trials of this method in 1999 and 2001 and did not find it to be effective.

Assessment: We do not recommend further use of this method.

9. Grizzly Dam modifications. Pike could become established in downstream areas through movement past Grizzly Valley Dam. In south central Alaska for example, northern pike were planted in a headwater lake in the nineteen fifties or sixties. Over the next several decades they spread downstream into the Yentna and Susitna Rivers through a series of floods (Stratton, pers. comm.).

Pike eggs, larvae, and possibly small juveniles can go through the outlet pipes, over the spillway during a spill, or through a temporary siphon used when upkeep is required on the dam structure and flow must be maintained in the creek. Adult pike can go over the spillway during a spill or through the siphon.

In 1996 the California Department of Water Resources installed metal graters at the two outlet pipes at the dam base (Rischbieter, 2000). The graters are not effective on pike larvae or eggs. Biologists monitor the area below the graters and, to date, have not found intact pike or pike parts. They have, however, captured live brown bullheads about 2 inches long on several occasions. Dead, but intact, golden shiner and pumpkinseed, up to 4 ½ inches in length have also been recovered in the stilling basin below the dam.

Water normally leaves through outlet pipes via valves located at three different levels under the water surface and is released into Big Grizzly Creek at the base of the dam. When Lake Davis is full, the uppermost valve is 15 feet below the surface, the middle valve is 35 feet deep, and the low-level valve is 75 feet deep (Howell, pers. comm.).[c] The Department of Water Resources now tries to use the lowest valve possible to reduce the chance of entrainment of pike eggs, larvae, and juvenile.

The historical record predicts that Lake Davis will spill five times each century. This is because the amount of runoff that the reservoir can receive during a large storm or rapid snowmelt can easily exceed the limited capacity of the outlet pipe at the base of the dam. The outlet pipe can release a maximum of

[c] Intake structures are at elevations of 5,760, 5,740 and 5,700. Full reservoir surface elevation is 5,775 feet above sea level.

about 13,000 acre-feet in a month, whereas inflow is often higher than this (Table 4) (Howell, pers. comm.). If there is not enough room in Lake Davis for the extra water, the excess pours over the spillway. Such events have occurred recently in 1983, 1986, and 1995. If spill over the spillway occurred during April or May, pike eggs, larvae, juveniles or adults could leave over the spillway and colonize new areas in California.

Table 4. Recent high inflow periods, Lake Davis

Time period	**Inflow to Lake Davis (acre-feet)**
December 1996 through January 1997[d]	30,908
March through May 1995[e]	61,251
March through May 1993	39,550
January through April 1986	47,355
February through June 1983	68,262

Department biologists consulted with engineering staff and the Department of Water Resources regarding additional methods to prevent pike escapement. They discussed methods to prevent entrainment in spillway waters including sandbagging the spillway or installing nets, inflatable weirs, self-cleaning screens or a fatal electric barrier. Below the dam, there is not enough space in the narrow channel for a screen with the needed capacity. Any of these ideas would require engineering evaluation and approval by the Department of Water Resources Division of Dam Safety.

> ***Assessment***: We recommend that the Department continue to work with the Department of Water Resource to reduce the risk of pike escape through Grizzly Valley Dam or over the spillway.

10. Fyke and trap nets. Field crews used trap nets most extensively in the spring immediately following ice-out. They placed up to 21 trap nets in areas along the shore where pike were moving into spawning areas. They checked the nets at least twice a week and removed them when no longer catching pike. Trap nets caught a large proportion of larger pike. Most of the 167 pike captured in the trap nets were spawners, and about one-third of pike were longer than 24 inches.

[d] If the rain had continued in January 1997 the reservoir would have spilled. It reached elevation 5,774.95 just about one half inch below spill.

[e] Grizzly Valley Dam did spill in May 1995. With a maximum release of 238 cubic feet per second (cfs) , the reservoir spilled for 22 days, with a maximum spill rate of 8.7 cfs (elevation 5,775.20), and a total of 236 acre-feet spilled.

Assessment: We recommend continued use of trap nets in 2003 and 2004, with more trap nets set during the 2004 spawn.

11. Stock brown trout. The Department planted about 160 broodstock in 1999 and over 1,000 in 2000. The Department has not continued to stock the non-native brown trout because there is no evidence that they are effective predators of pike.

Assessment: We do not recommend further implementation of this method.

12. Enforcement. The *Y2K Plan* outlines an enforcement plan including daily enforcement patrols, continuing investigation, including DNA research, and increasing and publicizing a reward leading to arrest and conviction for the unlawful movement or introduction of northern pike.

The Department hired a warden specifically for the Lake Davis area. The State legislature changed the state Fish and Game Code to increase the penalty for transporting aquatic nuisance species, such as the northern pike, to up to $50,000 and/or imprisonment up to one year. The violator is also liable for resulting property damages.

The Department hired researchers at the University of California, Los Angeles (UCLA) to conduct genetic analysis of northern pike populations using mitochondrial and nuclear DNA sequencing and microsatellite analysis. This work indicates that the pike in Lake Davis are genetically similar to the ones that were in the reservoir before the 1997 rotenone treatment. This could mean that the treatment did not eradicate the pike or that they were reintroduced from the same population a second time. The UCLA researchers are examining additional possible source populations to determine if the latter is the case. The relatively high level of genetic variation suggests that several hundred individuals either survived the treatment or were placed in the reservoir afterwards (CDFG, 2000).

Assessment: We recommend continuing law enforcement efforts.

13. Public education. The Department and the Steering Committee are trying to keep the public fully informed about the pike situation at Lake Davis. The Department now operates an office in downtown Portola staffed by biologists, employs field crews at Lake Davis during the field season, posts signs around the reservoir and in local stores and motels, publishes a biannual newsletter and a northern pike "watch card", holds periodic public meetings, and is maintaining a web site (www.dfg.ca.gov/northernpike). Department staff participates in the Lake Davis Steering Committee and works with a study group interested in water quality issues.

Assessment: We recommend continuing work on education and outreach.

MONITORING

The *Y2K Plan* suggests a wide array of monitoring activities. To be able to spend more time on pike removal, we chose electrofish monitoring of designated shoreline areas to assess abundance of pike and trout in Lake Davis. We used angling surveys to assess angling success. We also monitored pike diet by examining stomach contents.

Electrofish Monitoring to Assess Pike and Trout Abundance

Methods:

Crews sampled six separate sections of the shoreline over a five to eight day period using boat electrofishers during daylight hours (Figure 1), electrofishing the entire shoreline of the section in one pass. They measured or classified all fish by size. When possible, crews monitored monthly from March to December, depending on reservoir conditions. Biologists calculated an annual mean daily catch rate, an annual mean daily catch rate by section and a monthly mean daily catch rate for both pike and trout. We present results for pike and trout in 2000, 2001, and 2002 (Figures 2, 3 and 4). We will provide more detailed information, including information on catch rate for other fishes, in annual field season reports.

We express catch rates as the number of pike captured per hour of "pedal down time," referring to the time that the electrofishing gear transmits a mild electric current through the water. Workers press the pedal in a rhythmic manner, not continuously. A typical work day includes about two to four hours of "pedal down time."

We assume pike greater than 12 inches total length are one year and older, and will be of spawning age the following spring. We also examined changes in catch rate for pike longer than 15 inches.

Northern pike catch rate results:

The annual mean daily catch rate for pike increased significantly[f] from less than one pike per hour in 2000 to nearly four pike per hour in 2001 to eight pike per hour in 2002.

The annual mean daily catch rate for pike longer than 12 inches remained in the range of 0.2 to 0 .3 pike per hour (1 pike every 3 to 5 hours) each of the three years. While this rate remained about the same when examined on an annual basis, late summer and early fall catch rates for the larger fish peaked at

[f] $F_{(2, 148)} = 14.07518$, $P < 0.05$

their highest levels yet in 2002. In 2002, crews captured larger pike at rates of over 1, 4 and two 2 per hour in August, September and October, respectively. In the two previous years, they never captured large pike at a rate over 1 pike per hour. (Figure 2).

The annual mean daily catch rate for pike longer than 15 inches was about 0.1 pike per hour in 2000 (about one pike for every 10 hours of pedal down time) and rose to just less than 0.3 pike per hour (about 1 pike every 3 ½ hours) in 2003. Because of high variation in daily catch rates, however, these results are not statistically significant.

The overall mean daily pike catch rate varied by location (Figures 1 and 3). The highest annual catch rate was in the Mosquito section each year for all sizes of pike combined, peaking at about 18 pike per hour in 2002. In general, the lowest catch rates were in Grizzly Dam section, peaking at about 2 pike per hour in 2002. The catch rate increased annually in each section between 2000 and 2002.

For pike longer than 12 inches, the sections with the highest catch rate varied from year-to-year. In 2000, the highest rate was in Mosquito, at one pike per hour. In 2001, the catch rate was highest in Eagle Point and Grizzly Dam at about 0.6 pike per hour (about 1 pike every 3 hours). In 2002, larger pike were caught at a rate of 2 per hour in Freeman, and over 1 per hour in Jenkins, Eagle Point and Five Tree.

Figure 2. Northern pike catch rate during monthly monitoring, 2000-2002.

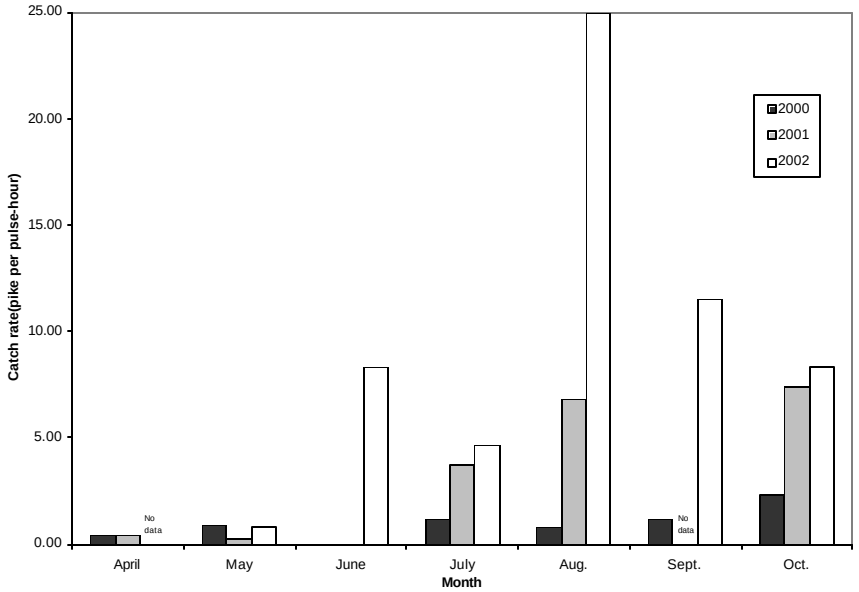
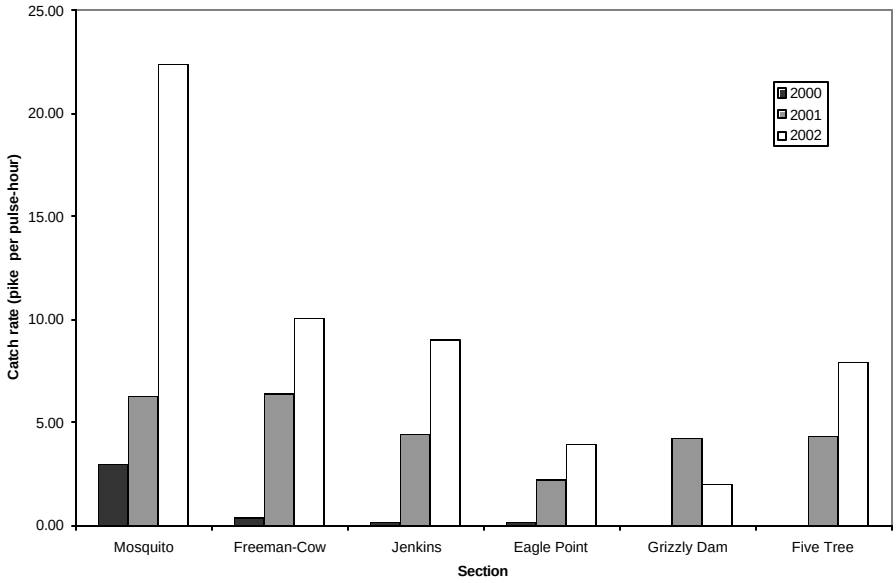


Figure 3. Northern pike catch rate during monthly monitoring by section, 2000-2002.



At Grizzly Dam, the catch rate increased from less than 1 pike per hour to over 2 pike per hour. In 2000, crews did not catch any large pike in Grizzly Dam section. In 2001 and 2002, they caught large pike at rates of 0.6 and 0.4 per hour (about 1 pike every 3 to 5 hours). The catch rate in Eagle Point section increased from less than 1 pike per hour to about 5. For larger pike, the rate has increased from about 0.1 (1 pike every 10 hours) to over 1 pike per hour.

The southernmost extent of pike spawning, which includes location of eggs, larvae, and juveniles, appears to be north of Camp 5 boat launch about 3 miles from Grizzly Valley Dam. Suitable spawning habitat is present along most of the perimeter of the reservoir including areas adjacent to the dam. As pike become more abundant, these areas will probably be used for spawning, further increasing the odds of escape over the spillway or through the outlet structure.

Discussion:

Several facts limit our ability to use catch rate as an exact measure of pike abundance. The density of pike in the shallow shoreline monitoring areas is not representative of pike density throughout the reservoir. During the summer, larger pike tend to inhabit areas of the reservoir below the effective zone of the electrofishing boat. The electrofishing boat may not be equally effective in

stunning fish of different sizes. Seasonal changes in the locations of various size-classes of pike vary, both within the year and from year-to-year. Most of the year, larger pike are in deeper water, so are probably underrepresented in our sample. Also, pike move in and out of this 6-foot deep area on a seasonal basis. Young-of-the-year, for example, frequent the shallow areas early in the season, but may disperse to deeper areas later in the year. The effectiveness of the electrofishing boat may also fluctuate with seasonal changes in water electroconductivity. For these reasons, our catch rate data should not be used as a precise estimate but only as a general indicator of changes in pike abundance.

The increasing annual catch rates for all sizes of pike strongly suggest that the pike population is increasing. The small increases in annual catch rate for larger pike suggests that the population of larger (both greater than 12 inches and greater than 15 inches) pike is remaining constant or growing much more slowly than the population as a whole. The largest catch rates yet for pike longer than 15 inches have occurred in 2002 along the west side of the reservoir in Freeman, Jenkins and Eagle Point, indicated increasing densities in those areas.

Pike produce about 10,000 eggs per pound of a female's body weight (Lagler, 1956). A typical spawning female in Lake Davis in 2003 contained about 34,000 eggs.[g] The number of pike eggs that survive to the size of a fingerling fish varies tremendously, depending on water temperature, oxygen content, suspended sediment, water level and number of predators. If the number of surviving fingerling offspring ranges between 0.037 and 0.4 percent as reported in the literature (Billard, 1996), then the female pike described above produces between 13 and 136 surviving fingerlings each spring. The known predators on adult pike in Lake Davis are bald eagle, osprey, pelicans and of course humans. There are no known effective fish predators on pike.

While we hoped to increase pike mortality though the various pike removal methods, it is important to realize that the very reproductive nature of pike has evolved to compensate for high mortalities. Death by gill net, electrofishing boat and other gear may impact pike numbers but will not be able to completely overcome the pike's naturally high fecundity and the favorable Lake Davis fry survival conditions.

Pike have evolved several compensatory mechanisms to ensure survival. They may, for example, mature earlier if no other spawners are in the area or if fishing pressure reduces their numbers (Diana, 1983). They tend to grow faster and produce more eggs when the population is less dense. They will have higher fry survival rates when their numbers are scarce, in part because there are fewer chances for cannibalism (Foin, 2003). All these strategies make it difficult to impact the population. If more pike are pulled out of the reservoir,

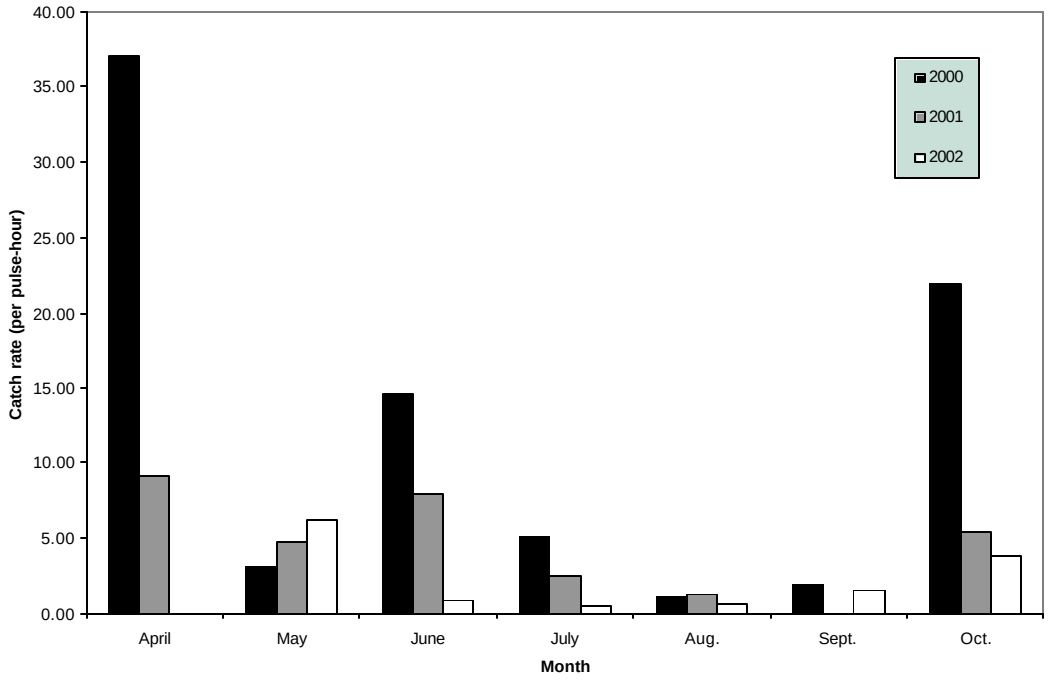
[g] In March and April 2003 about 98 females were captured before or during their spawn, with an average weight of 3.4 pounds.

these compensating mechanisms kick in. One modeler estimated that it would be necessary to remove 50 percent of the adult pike on an annual basis to keep the adult population from growing (Foin, 2003).

Rainbow trout catch rate results:

The catch rate for rainbow trout declined significantly[h] during the 3-year period (Figure 4). In 2000, the mean annual catch rate was over 10 trout per hour, declining to about 4 per hour in 2001 and less than 3 per hour in 2002. Declines occurred during each month, except for May, which had a slight increase in catch rate.

Figure 4. Catch rate for rainbow trout during monthly electroshock monitoring, 2000-2002.



[h] $F_{(2, 148)} = 9.628804$, $P < 0.05$

Angler Surveys

Methods:

The Department conducted creel censuses from one to seven days per month, April through November, each year from 2000-2002. Staff surveyed anglers at the boat ramps and along the shoreline, tallying and measuring creeled fish. Staff recorded the number of anglers in each party and the number of hours fished.

Results:

Angler catch per hour for rainbow trout declined significantly[i] from an average of 0.293 in 2000 to an average of 0.161 in 2002. While catch rate declined, the average length of rainbow trout caught increased significantly[j] from an average of 16.0 inches in 2000 to 16.2 inches in 2002.

Discussion:

Angler survey results indicate that trout are less abundant in Lake Davis in 2002 than they were in 2000. Many factors undoubtedly contributed to the decrease in angler catch per hour and the increase in average size of rainbow trout caught during the three year period. The Department extensively stocked the reservoir in 1998 and 1999 to reestablish the rainbow trout fishery after chemical treatment to eradicate pike, planting over three million fingerlings, 400,000 subcatchable-, and 160,000 catchable-sized trout. In the years 2000-2003, the Department planted an average of 55,000 catchable-size trout annually. This approximates a standard stocking plan of 10 catchable-size trout per surface acre for a lake fishery the size of Lake Davis. The Department revised the stocking plan in 2000 to discontinue planting fish smaller than catchable-size because of the presence of pike and the management steps to reduce pike food supply. Given that there are only three years of data, that there is great variation in the annual trout planting, and that the fishery is reestablishing after treatment, it is difficult to draw any conclusions about the effect that pike may be having on the fishery at this point.

Pike diet

Methods:

Biologists examined the stomach contents of a subsample of each size class of pike removed from Lake Davis between May and December 2002. They cut open the stomachs with scissors or scalpel and identified invertebrates to taxonomic order and counted the fish, identifying them to species. They did not

[i] $F_{(2, 1402)} = 4.635383$, $P < 0.05$
[j] $F_{(2, 1437)} = 45.75239$, $P < 0.05$

try to weigh or estimate the volume of the stomach contents or count the number of invertebrates. A general description of the 2002 stomach content analysis is presented here.

Results:

Biologists examined a total of 2,293 stomachs from pike ranging in length from less than 2 inches to 33 inches. The average length of pike examined was 10 inches. About a third of the pike had empty stomachs. Of the 1,475 stomachs with contents, 29 percent contained only fish, 64 percent contained only invertebrates, and 2 percent contained toad or frog tadpoles. About 4 percent contained a mixture of those categories.

The diet of larger pike was much different than that of the smaller pike. If a pike less than 16 inches long had something in its stomach, most of the time it was strictly invertebrates. If a pike longer than 16 inches had something in its stomach, it was almost always fish. The most common fish was trout. Pumpkinseed sunfish and northern pike were the next most common items. Although we did not weight the stomach items, we estimate that the trout, usually the largest of the prey items noted, comprised about 75% of the contents of the pike stomachs.

Table 5. Types of food found in northern pike stomachs in 2002

General category of food	Times encountered	Percent
Invertebrates only	946	64%
Fish only	432	29%
Invertebrates and fish	48	3%
Amphibians	35	2%
Invertebrates and amphibians	7	<1%
Unidentified	7	<0%
Total:	1,475	
Note: 2,293 stomach examined; 818 (36%) were empty		

Table 6. Type of food found in stomach of northern pike >16 inches long in 2002.

Category of food item	Times encountered	Percent
Fish only	97	91%
Invertebrates only	7	7%
Fish and invertebrates	3	3%
Total:	107	
Note: 227 stomachs examined; 120 (53%) were empty		

Table 7. Types of fish found in stomachs of northern pike > 16 inches long in 2002.

Fish species	**Number of stomachs containing species**	**Percent of non-empty stomachs containing species**
Rainbow trout (*Oncorhynchus mykiss*)	55	51%
Pumpkinseed sunfish (*Lepomis gibbosus*)	20	19%
Northern pike (*Esox lucius*)	15	14%
Golden shiner (*Notemigonus crysoleucas*)	9	1%
Unidentified	4	4%

Note: 97 pike > 16" had fish in the stomach. Sometimes more than one species was present.

Discussion:

Two laboratory studies that measured the minimum, maximum, and optimal amounts of food pike need to survive determined that the optimal amount of food for a 0.7 ounce (20 gram) pike in 59 degrees F (15 degrees C) water is 3.2% of the body weight of the pike per day (Billard, 1996). This would mean that a 15-inch-long pike (about 12 ounces) eats about 8¾ pounds of food per year under the best feeding conditions. If 75% of northern pike diet by weight is trout, a pike would consume about 6½ pounds of trout per year. This equates to about 13 catchable-size trout per year.

In 2002, about 200 pounds of the pike harvest included pike greater than 15 inches long. If the harvest represented 10% of the pike of that size in the reservoir, there were about 1,800 pounds remaining in the reservoir, with an appetite for over 31,000 catchable trout, or over one-half of the annual reservoir plant. A more optimistic estimate that we are harvesting 25% of the pike longer than 15 inches would mean that only 600 pounds remained in the reservoir at the end of the 2002 season. This amount of pike biomass would consume about 10,000 catchables annually.

CONCLUSIONS AND RECOMMENDATIONS

The following criteria provide an indication of the effect that pike plan implementation may be having on the Lake Davis pike population.

1. Changes in pike density in Lake Davis: The pike population grew during the first three years of plan implementation, but growth may have slowed in year four. Catch rate data indicated that density of smaller pike most likely increased dramatically between 2000 and 2001 and again in 2002. Catch rate data for July 2003 (at the time of the completion of this report) dropped to a level below that of July 2002 for young-of-the-year pike. It is too early, however, to determine if the 2003 harvest and overall catch rates will be lower than that of 2002.

2. Impact to the trout fishery: Catch rate data indicated that the density of larger pike may have remained about the same during the 3-year period, although they may have become more abundant along the west side of the reservoir. One 15-inch-long pike probably eats about 13 catchable-size trout annually and it is estimated that trout comprised at least three-quarters of the diet of pike 16 inches and longer. Angler survey and monitoring data indicated that trout densities in Lake Davis have decreased. This may have been partly due to pike predation but was also likely a reflection of a decrease in annual stocking numbers beginning in 2000 after an unusually large stocking program in 1998 and 1999.

3. Changes in the risk of pike escaping: Increased pike abundance suggests that the risk of pike escaping increased during the course of plan implementation. Pike numbers increased and by June 2003 adult pike were found in all sections of the reservoir. Plan implementation may have slowed spawning area expansion and thus the extent of eggs, larvae and juveniles. Uncontrolled spill and the consequent risk of entrainment of eggs, larvae, juveniles and adults can be expected about five times each century.

4. Changes in the risk of human movement of pike: Although both education and enforcement activities may have reduced the risk of human movement of pike, increases in pike density (and therefore the ease of catching pike) may have cancelled out these effects. Human movement probably remains the most likely method of northern pike being introduced to other waters from Lake Davis. This is a current and ongoing risk. As the pike density in Lake Davis increases, the ease of catching pike and the risk of humans moving them to other locations increases as well.

We recommend a few short-term changes to improve current implementation of the *Y2K Plan*. Some of the thirteen original activities should be removed from the implementation list: planting of brown trout, herding pike with electrofishing boats, blocking spawning areas, and using detonation cord. We recommend upkeep and alteration of the barrier net to improve its

effectiveness at low reservoir elevations, stepped-up trap-netting, gill-netting and purse-seining efforts during the spring spawn, and working with the Department of Water Resources to develop a method to further reduce chances of pike escape during reservoir spill.

Over the long term, the risk of natural or human-induced movement of pike to other waters remains unless pike are eradicated from the reservoir. The four assessment criteria indicate implementation of the *Y2K Plan* has not stopped the growth of the pike population, reduced the threat to the trout population or reduced the threat of natural or human movement to other waters. The *Y2K Plan*, however, may have slowed the growth of the pike population in Lake Davis and the threats may be less than had there been no plan in place. Pike have compensatory strategies such as more rapid growth rates, earlier maturation, and higher fecundity when densities are low. These strategies, combined with extensive and excellent spawning and rearing habitat in Lake Davis, may mean that reducing pike densities by manual or mechanical means will not work. And, because rapid pike reproduction will quickly wipe out any gains, removal efforts must be ongoing and uninterrupted.

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